4157

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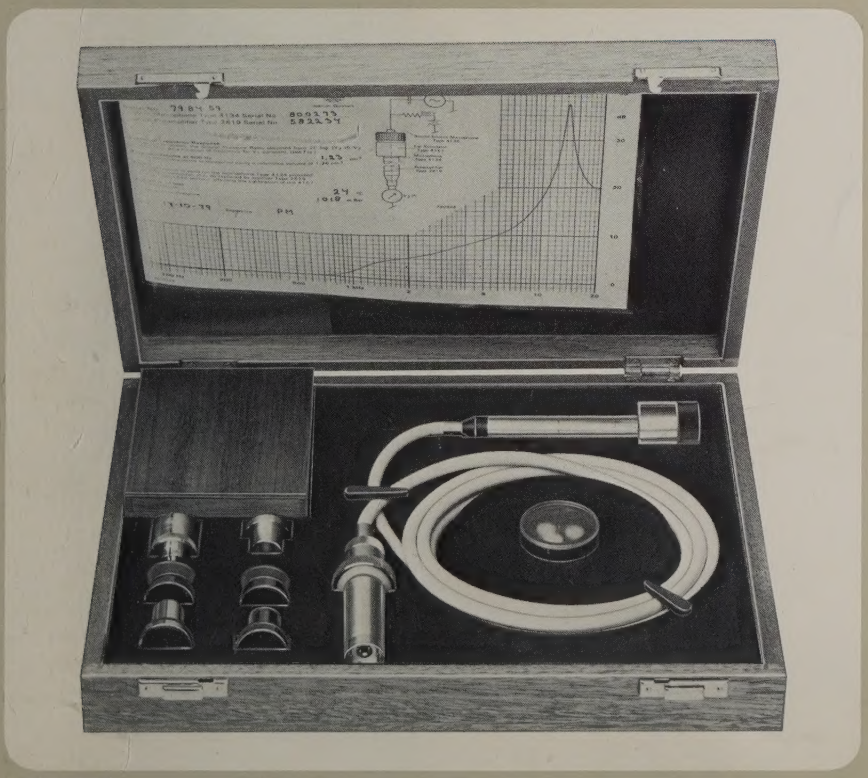
Instruction Manual

Ear Simulator Type 4157



The Ear Simulator Type 4157 is designed to provide stable, well-defined acoustic conditions for testing earphones, and hearing aids connected to the ear by insert earphones, ear inserts or personal ear moulds. It closely reproduces the physical and acoustical parameters of the actual human ear, providing the earphone under test with a similar acoustical impedance, and complies with ANSI and proposed IEC standards.

Brüel & Kjær

033-0629

EAR SIMULATOR
TYPE 4157

September 1980

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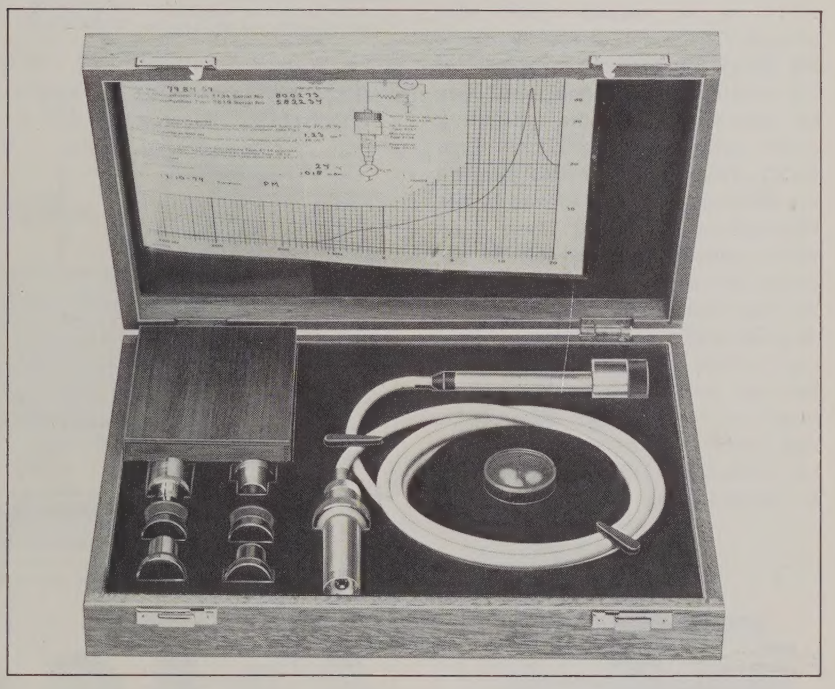
Type 4157
Ear Simulator

USES:

- Frequency response and sensitivity measurements on hearing aids using insert earphones
- Servicing of hearing aids
- Production testing of earphones

FEATURES:

- Conforms to proposed IEC and ANSI Standards
- Simple and straightforward calibration procedure
- Well defined measuring conditions
- Individually calibrated
- Wide range of accessories included



Description

The Ear Simulator Type 4157 is primarily intended for measurements on hearing aids using air conduction earphones coupled to the ear by ear inserts such as tubes, plugs or personal ear moulds. It has therefore been designed to fulfil the requirements of the proposed IEC and ANSI standards for an ear simulator for measurements using insert earphones. The Ear Simulator Type 4157 closely reproduces the physical parameters of the human ear, presenting the insert earphone under test with an impedance approximating that of the real human ear.

The Ear Simulator consists of a main housing into which are assembled a number of rings whose shapes form annular air volumes connected to the main volume of the housing by air passages. The main ear canal volume is of a similar shape and volume to that of the actual human ear and provides a similar acoustic impedance to the insert earphone being tested. The combined Microphone Type 4134 and Preamplifier Type 2619, supplied with the set, are screwed directly into the housing of the Ear Simulator, terminating the main ear canal volume.

To ensure that measurements are reproducible and can be compared with each other, a reference measurement plane is defined, see Fig.1. This is perpendicular to the ear canal axis at the normal position of the tip of the ear mould.

The Type 4157 is delivered in a mahogany case with an Individual Calibration Chart giving all parameters for its correct use (see Fig.2).

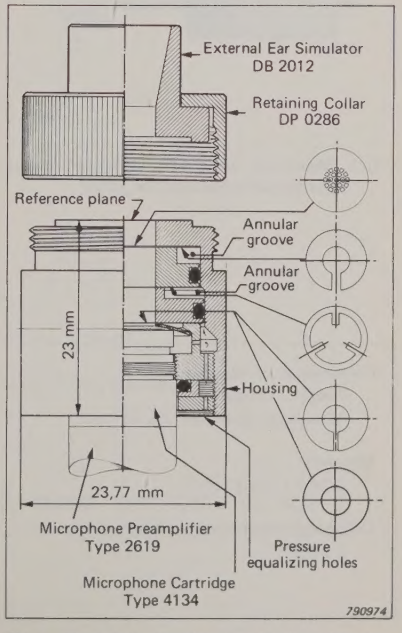


Fig.1. Sectional drawing of the Ear Simulator showing external ear simulator DB 2012 and clamping collar

Accessories

A number of adaptors, which can be mounted flush with the reference plane, are delivered with the Ear Simulator, both for mounting a wide range of earphones in current use and for special measurements on the Ear Simulator itself. See Fig.4.

The ear mould simulator DB 2015 is for testing insert earphones. The external ear simulator DB 2012 simulates the whole of the external ear channel, and may be used to calibrate the measuring chain with the Pistonphone Type 4220. When used for this purpose the calibration level produced by the Pistonphone is 0,8 dB lower than when calibrating a microphone because of the much larger volume of the Ear Simulator cavity. The ear plug simulator DP 0370 is for testing behind-the-ear hearing aids. The ear mould holder DS 0540 is used to mount small ear moulds and in-the-ear hearing aids on the Ear Simulator. DS 0541 is similar to DS 0540 but for larger moulds.

The Tube stud DP 0368 is for modular hearing aids.

Adaptor DP 0276 accepts a 1/4 inch microphone to be used as a sound source for testing the Ear Simulator, and UC 0124 is a special tool for removing the microphone.

The adaptors are secured by an internally threaded collar DP 0286.

For Customers already possessing a Preamplifier Type 2619 or 2642, the Ear Simulator set can be delivered without the Preamplifier Type 2619.

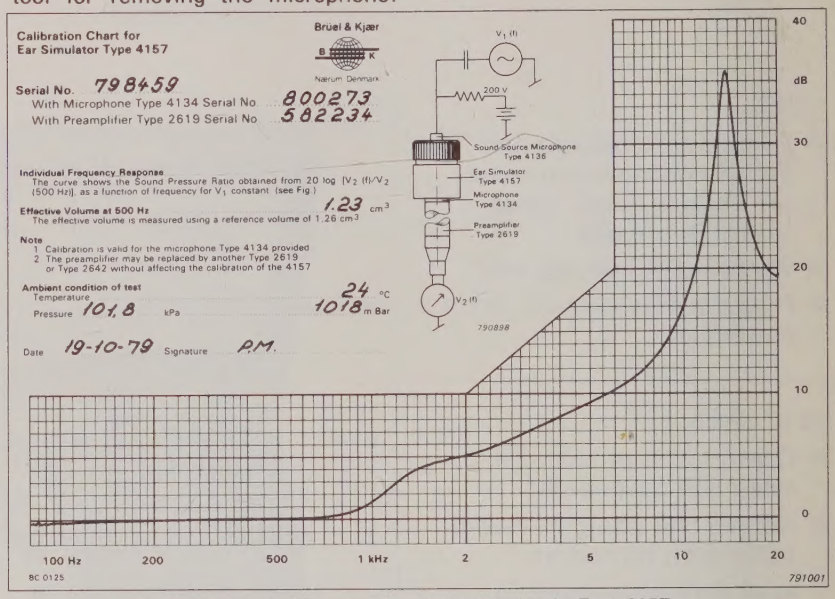


Fig.2. Individual calibration chart delivered with the Type 4157

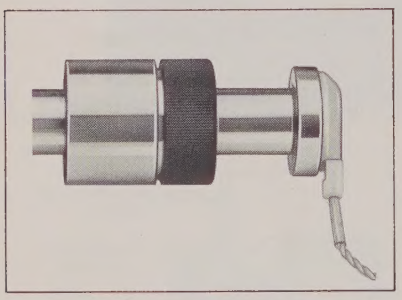


Fig.3. Mounting an insert earphone using ear mould simulator DB 2015

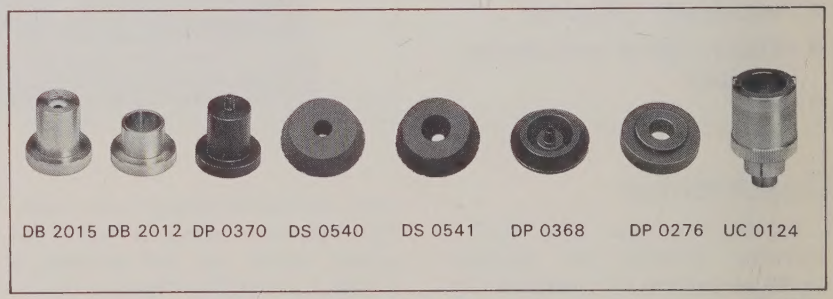


Fig.4. Accessories delivered with the Type 4157. Left to right: ear mould simulator DB 2015, external ear simulator DB 2012, ear plug simulator DP 0370, ear mould holder DS 0540 ear mould holder DS 0541, tube stud DP 0368, 1/4-inch microphone adaptor DP 0276, microphone removal tool UC 0124

Specifications 4157

Dimensions of Housing:
Height: 23 mm
Maximum diameter: 23,77 mm

Volume:
1,260 ± 0,030 cm^3

Calibration Temperature Range:
23 ± 3°C

Calibration Ambient Pressure:
101,3 ± 3 kPa (1013 ± 30 mbar)

Resonant Frequency:
14 ± 1 kHz

Accessories Included:

Calibration Chart	
Condenser Microphone	Type 4134
Microphone Preamplifier	Type 2619

External Ear Simulator	DB 2012
Ear Mould Simulator	DB 2015
Tube Stud	DP 0368
Ear Plug Simulator	DP 0370
Ear Mould Holder	DS 0540
Ear Mould Holder	DS 0541
1/4 inch Microphone Adaptor	DP 0276
Microphone Removal Tool	UC 0124
Retaining Collar	DP 0286
Dust Protector	DS 0535

2. OPERATION

2.1. PRELIMINARY

A sectional view of the Ear Simulator Type 4157 is reproduced in Fig.2.1, showing the internal construction and the separating rings in detail.

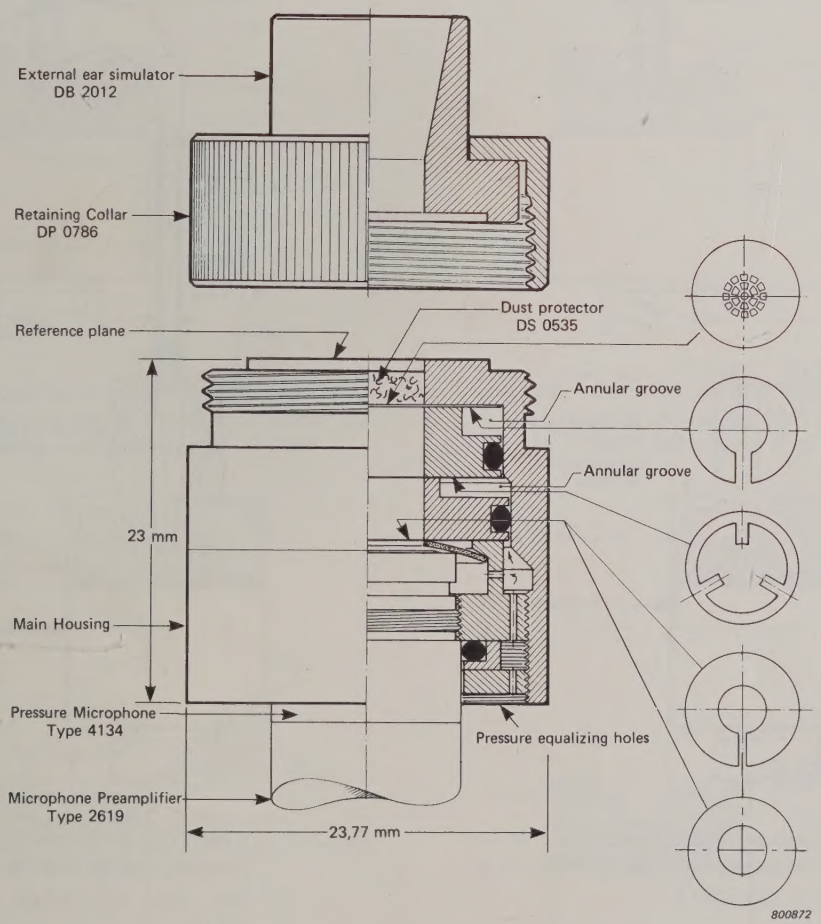


Fig.2.1. Sectional view of the Ear Simulator Type 4157 including the retaining collar and external ear simulator

The Ear Simulator is delivered fully assembled and calibrated, and ready for use. It remains only to mount the correct adaptor to connect the earphone or hearing aid on which the measurements are to be carried out.

2.2. COUPLING THE EARPHONE TO THE EAR SIMULATOR

The wide range of adaptors supplied with the Ear Simulator enables easy coupling of all types of insert earphones and hearing aids. The earphone (or ear plug or ear mould simulator) must always be mounted level with the reference plane of the Ear Simulator to obtain the greatest repeatability of measurements. The ear plug simulator (DP 0370), the ear mould simulator (DB 2015) and the tube stud (DP 0368) are correctly located automatically by the retaining collar. When coupling in-the-ear earphones, personal ear moulds, or ear inserts using the ear mould holders (DS 0540 or DS 0541), care should be taken to ensure that their openings are mounted level with the reference plane. Figures 2.2 to 2.8 show the various methods of coupling different types of hearing aids and earphones to the Ear Simulator using the adaptors supplied.

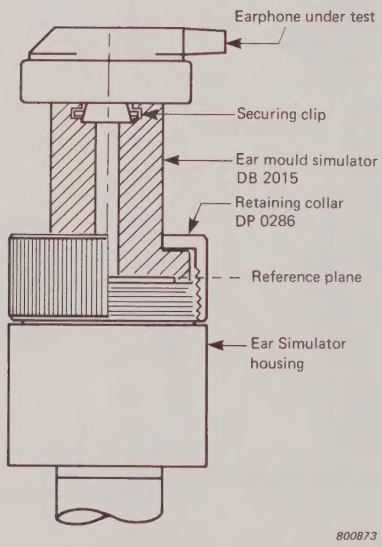


Fig.2.2. Coupling an insert earphone to the Ear Simulator using ear mould simulator DB 2015

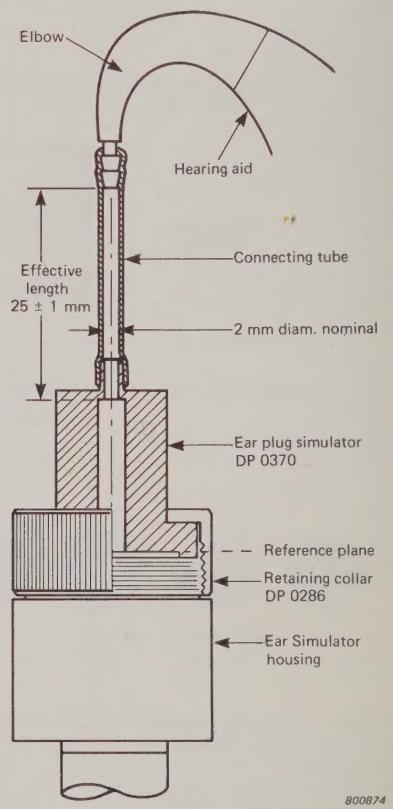


Fig.2.3. Coupling a behind-the-ear type of hearing aid to the Ear Simulator using the ear plug simulator DP 0370

The retaining collar should be screwed firmly, but not excessively tightly, onto the Ear Simulator housing to provide an air tight seal between the adaptor being used and the reference plane of the Ear Simulator. When using the ear mould holders (DS 0540 or DS 0541), the action of tightening the retaining collar compresses the holder so that it grasps the hearing aid, mould, or ear insert firmly, and provides an airtight seal. The two ear mould holders supplied have different internal diameters to deal with the majority of ear moulds and inserts of different sizes in common use.

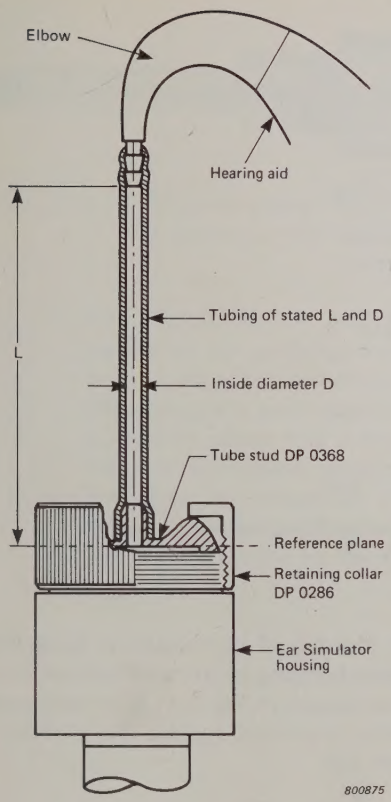


Fig. 2.4. Coupling a behind-the-ear type of hearing aid to the Ear Simulator by tubing using tube stud DP 0368

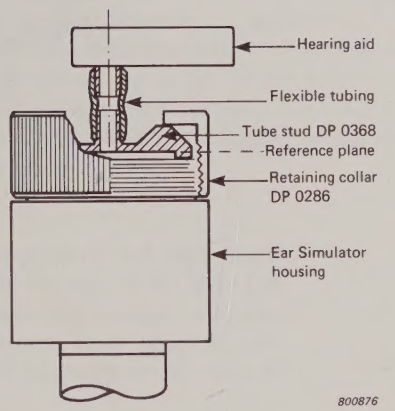


Fig. 2.5. Coupling an in-the-ear modular type of hearing aid to the Ear Simulator using tube stud DP 0368

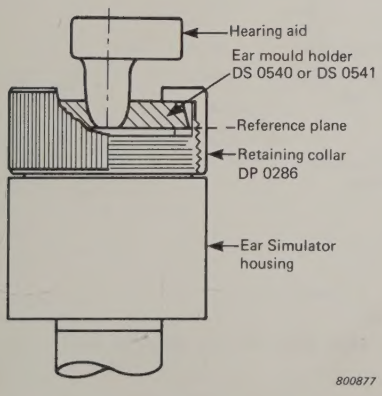


Fig. 2.6. Coupling a custom made in-the-ear type of hearing aid to the Ear Simulator using ear mould holder DS 0540 or DS 0541

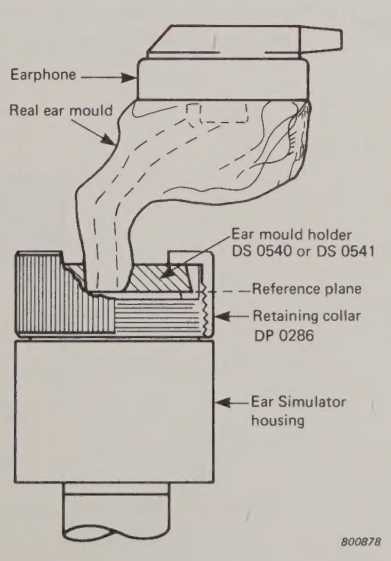


Fig. 2.7. Coupling an insert earphone connected to a real ear mould to the Ear Simulator using ear mould holder DS 0540 or DS 0541

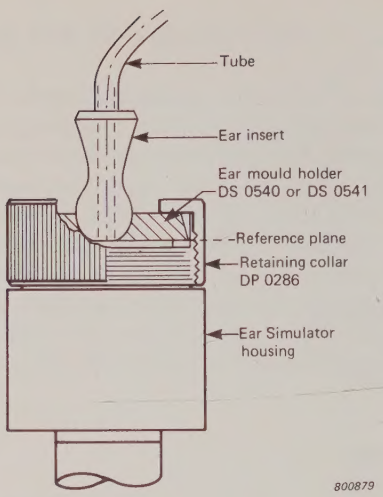


Fig.2.8. Coupling a real ear insert to the Ear Simulator using ear mould holder DS 0540 or DS 0541

Note: The Ear Simulator is delivered with a number of polyurethane foam dust protectors, DS 0535, which fit into the Ear Simulator housing at the end remote from the microphone, against the upper perforated disc, as shown in Fig.2.1. It is recommended that one of these dust protectors is always in place to protect against the gradual ingression of dust. Further details can be found in section 3.6.

2.3. CALIBRATION

Calibration of the measuring chain is most easily carried out using a Pistonphone Type 4220, which supplies a stable, accurate tone at 250 Hz, and can be fitted directly to the Ear Simulator after mounting the external ear simulator as in Fig.2.9. Fit the Pistonphone itself with the half inch microphone adaptor DB 0311, and press the Ear Simulator into the Pistonphone cavity, ensuring a good airtight fit. See Fig.2.10.

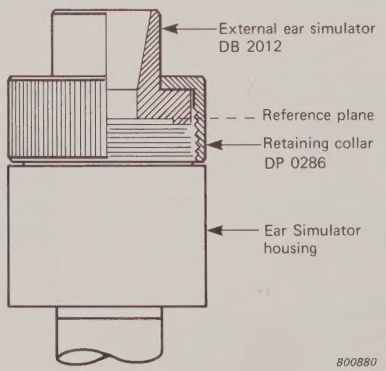


Fig.2.9. Mounting the external ear simulator DB 2012 on the Ear Simulator

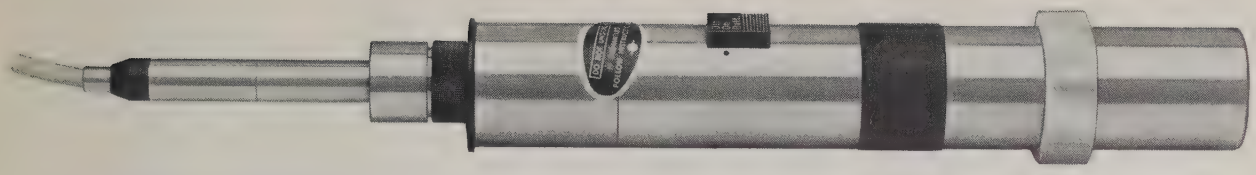


Fig.2.10. Calibration using the Pistonphone. The sound level produced is 0,8 dB lower than stated on the calibration chart

The Pistonphone's individual calibration chart states a value for the sound level produced by the pistonphone when connected to a standard one inch B & K microphone with a standard protection grid, or one of the smaller B & K microphones and their respective grids and adaptors, giving a standard coupler volume of 19,733 cm^3. The Ear Simulator cavity has a much larger volume however, and when the Pistonphone is used for this calibration purpose the sound level produced by it is 0,8 dB lower than that stated on its calibration chart. (See the manual for the Pistonphone Type 4220 for detailed explanation.) Thereafter the measuring chain is adjusted in the normal way using the reduced value for the Pistonphone sound level.

3. CHARACTERISTICS

3.1. FREQUENCY RESPONSE

The frequency response of each Ear Simulator is measured individually at the factory and a calibration chart which contains all the information necessary for correct use of the Ear Simulator as well as its frequency response characteristic is included with it. A typical calibration chart is reproduced in Fig.2 of section 1. Figure 3.1 shows the same frequency response compared with the limits imposed by proposed ANSI and IEC standards for an occluded ear simulator. The value at 500 Hz is taken as reference to express the amplitude in dB. In this case the absolute value is 35,6 MPa.s.m $^{-3}$. Further discussion of the measurement of the frequency response of the Ear Simulator using a sender microphone and the special adaptor DP 0276 takes place in section 3.5.

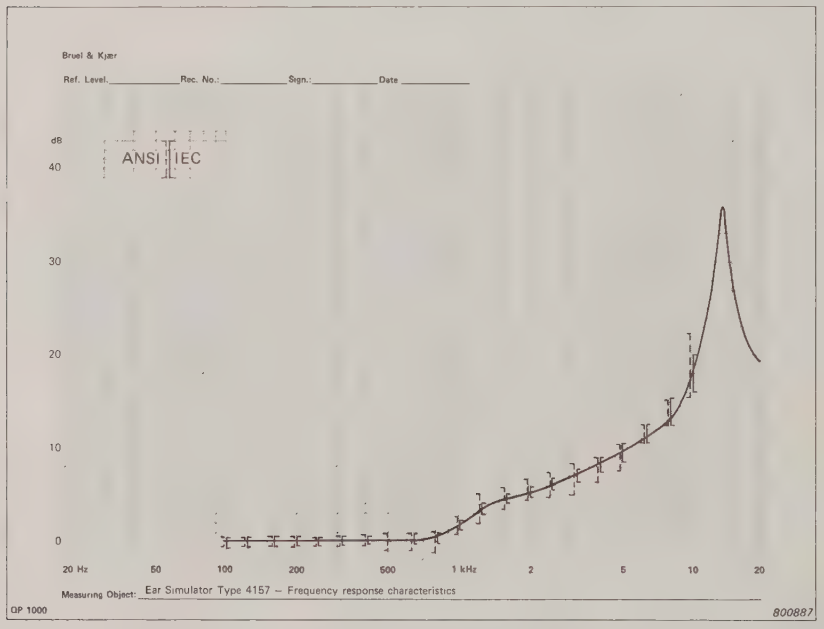


Fig.3.1. Frequency response of a typical Type 4157 Ear Simulator with the tolerances allowed by ANSI and IEC superimposed

3.2. PHASE CHARACTERISTICS

In addition to stating tolerance limits for the amplitude response, the ANSI Standard also gives limits for the phase response of the Ear Simulator. There are no similar limits stated by the proposed IEC standard. Figure 3.2 shows a typical phase response for the Type 4157 Ear Simulator with the ANSI tolerance superimposed.

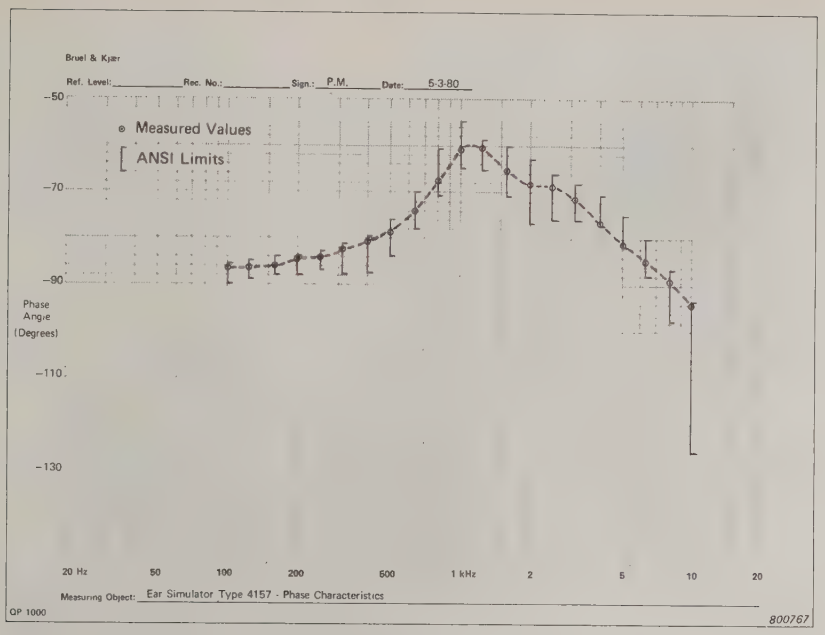


Fig.3.2. Phase characteristics of a typical Type 4157 Ear Simulator compared with the tolerances allowed by ANSI

3.3. INPUT IMPEDANCE

The input impedance is shown in Figure 3.3. The value at 500 Hz is used as the reference to express the amplitude in dB. For the example shown this value is 35,6 MPa.s.m^{-3}.

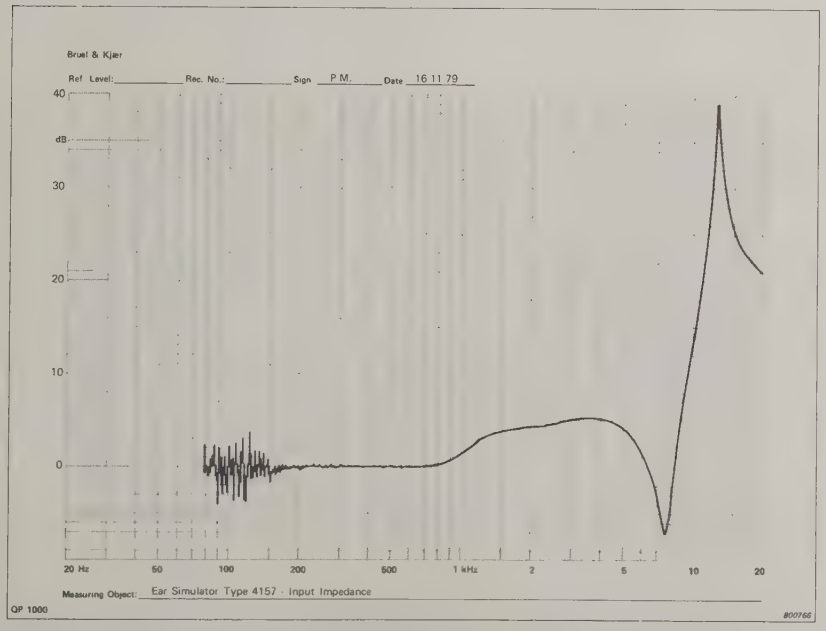


Fig.3.3. Input Impedance of a typical Type 4157 Ear Simulator

3.4. INFLUENCE OF AMBIENT PRESSURE CHANGES

The data and frequency response given on the calibration chart delivered with the Ear Simulator are for approximately normal atmospheric pressure conditions. For large changes in ambient pressure, for example at high altitudes, there are slight changes in the frequency response of the Ear Simulator. However, the tolerances on the frequency response are complied with for ambient pressures down to approximately 800 mbar (80 kPa.), corresponding to an altitude of approximately 2000 m. Frequency response curves for three values of ambient pressure are shown in Fig.3.4 showing the variability to be expected.

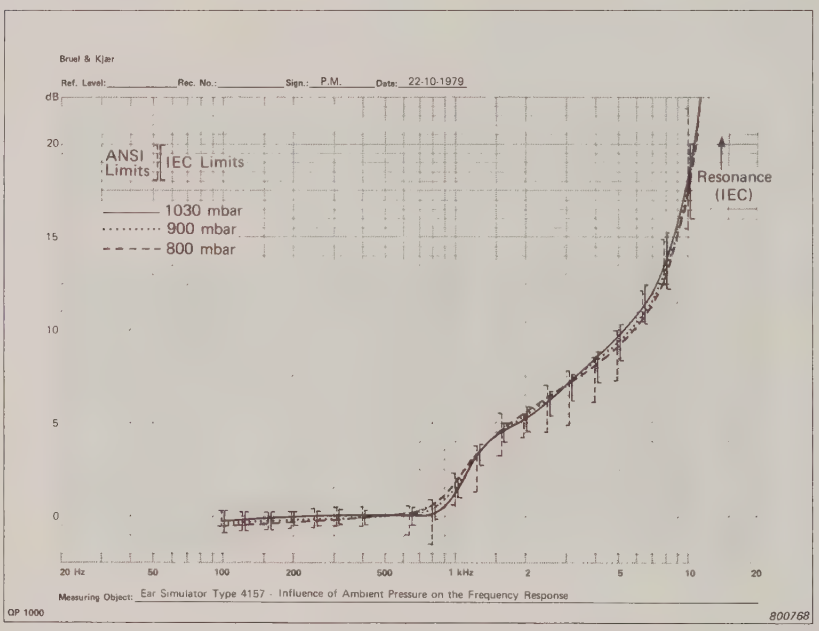


Fig.3.4. Influence of static pressure on the frequency response of the Ear Simulator Type 4157

3.5. DETERMINING THE FREQUENCY RESPONSE OF THE EAR SIMULATOR

The Ear Simulator Type 4157 is calibrated at the factory and supplied with all the data necessary for its correct use. However, to enable the user to carry out a frequency response calibration, the Ear Simulator is delivered with a special adaptor DP 0276 so that a quarter inch Condenser Microphone Type 4136 can be attached to operate as a sender microphone. Dismantling the Ear Simulator is not recommended unless absolutely essential. If it is dismantled for any reason, however, it should always be recalibrated after reassembly to ensure that it remains within tolerances. A measurement set-up suitable for carrying out these measurements is shown in Fig.3.5. A pure tone sinusoidal signal of constant amplitude is supplied to the sender microphone, through a special adaptor WA 0160, by the generator section of a Heterodyne Analyzer Type 2010. The signal from the built-in microphone of the Ear Simulator is analyzed in the analyzer section of the Heterodyne Analyzer and the resultant frequency response output to an X-Y Recorder Type 2308.

It should be noted that to obtain accurrate results at high frequencies above the normal range of use, i.e. above 10 kHz, and especially for measuring the resonance frequency of the Ear Simulator, it is necessary to seal the small annular gap between the sender

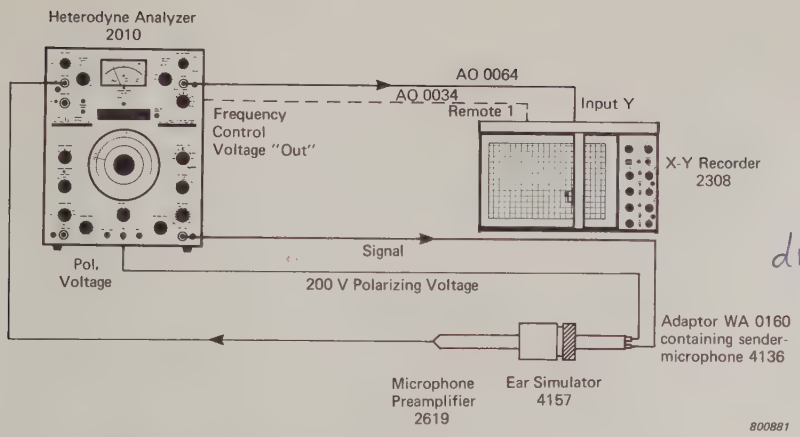


Fig.3.5. Measurement arrangement for determining the frequency response of the Ear Simulator

microphone and the adaptor DP 0276 with a special compound ("LITHELEN-Hochvakuum-Fett" is recommended) to make it airtight. The sealing compound should be introduced at the position shown in Fig.3.6.

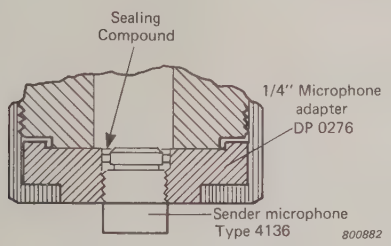


Fig.3.6. Method of sealing the volume between the quarter inch sender microphone and the microphone adaptor DP 0276 using a special sealing compound

Note: Great care must be excercised to ensure that the membrane of the microphone is not touched during this operation and that no sealing compound contacts its surface, as the membrane is delicate and easily damaged.

For normal calibration checks over the working frequency range of the Ear Simulator, i.e. from 100 Hz to 10 kHz, the error introduced by omitting this seal does not make a significant difference to the response which remains within tolerances, and may normally be left out. The effect of using and omitting the sealing compound is demonstrated in Fig.3.7. It can be clearly seen that the resonance frequency is a little lower if the gap is not sealed, although the frequency response below 10 kHz is not significantly altered and remains within tolerances.

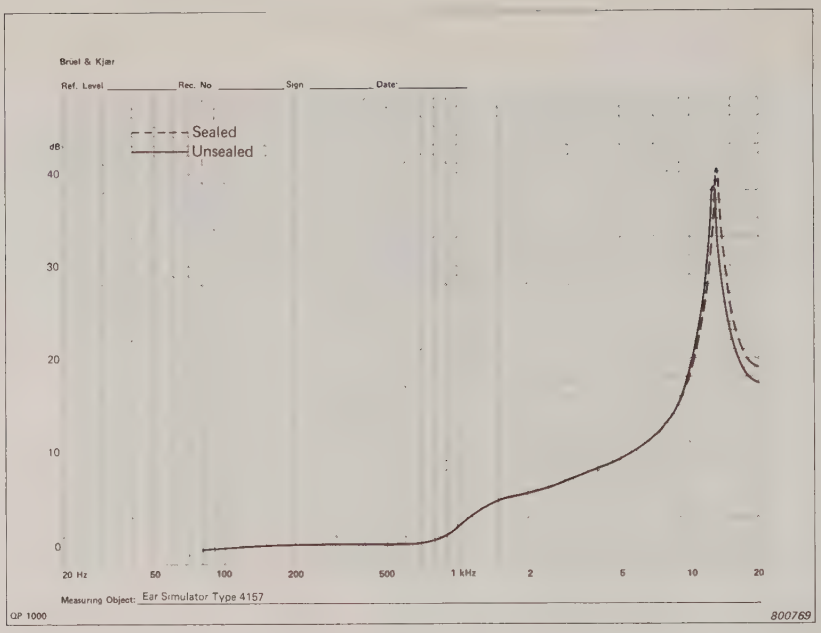


Fig.3.7. Influence of sealing the Sender microphone on the resonance frequency of the Ear Simulator

3.6. INFLUENCE OF THE DUST PROTECTOR

It is recommended that the dust protector DS 0535 is always kept in place in the Ear Simulator to prevent the ingression of dust which may slightly effect its characteristics in the long term. Using the dust protector has a small effect on both the frequency response and the resonant frequency. The changes are, however, not significant, as they lie within the tolerances on the frequency response, Fig.3.8 shows the frequency response measured with and without the dust protector, and clearly demonstrates the

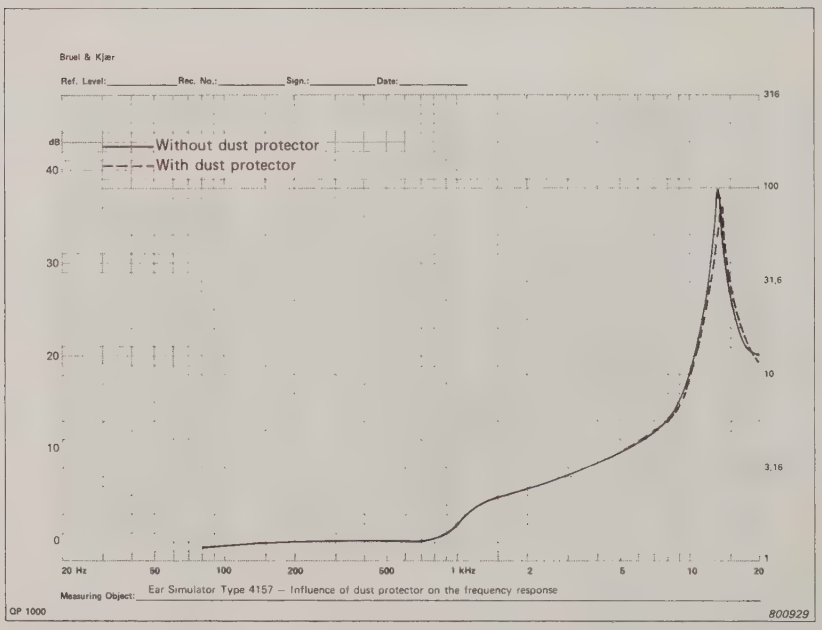


Fig.3.8. Influence of the dust protector on the frequency response

small difference between them. In practice, this difference lies within the accuracy of measurement.

3.7. REFERENCES

IEC TC29C/WG6 (Draft) Occluded-ear Simulator for the measurement of earphones coupled to the ear by ear inserts.

ANSI S3.25—1979 American National Standard for an Occluded Ear Simulator.

4. DISMANTLING AND REASSEMBLING THE EAR SIMULATOR

It should not normally be necessary to dismantle the Ear Simulator, and it is not recommended. However, if for any reason it becomes necessary to do so, it can be dismantled using the microphone removal tool UC 0124 as follows:

1. Unscrew the Ear Simulator from the Preamplifier.

2. Insert the two projecting pins of the microphone removal tool UC 0124 into the two corresponding holes in the securing ring DB 2223 and unscrew from the housing DB 2215. This releases the O-ring holder and O-ring which can be eased out by a small screwdriver or by tapping the housing gently against the hand. See Fig.4.1.a.

3. The microphone holder ring DB 2218 is now accessible and, together with the microphone, can also be screwed out of the housing using the removal tool as before. The microphone can now be screwed out of the holder. No attempt should be made to remove the plastic ring YO 0739 from the holder. The two spacers YO 0742 and OD 0319 can now be taken out. See Fig.4.1.b.

   Note: During this operation great care should be taken to ensure that the microphone diaphragm is not touched.

4. The other end of tool should now be inserted into the housing as shown in Fig.4.1.c and the screw in the centre of the tool tightened with a screwdriver so that it firmly grips the first coupler ring DB 2217 internally. This coupler ring, together with its O-ring can then be pulled out, enabling the spacer OD 0320 to be removed.

5. Use the same procedure to remove the second coupler ring DB 2216 and the final two spacers OD 0321 and YO 0740. See Fig.4.1.d.

6. The reassembly procedure is exactly the reverse of the above.

7. The calibration of the Ear Simulator should now be checked as in section 3.5.

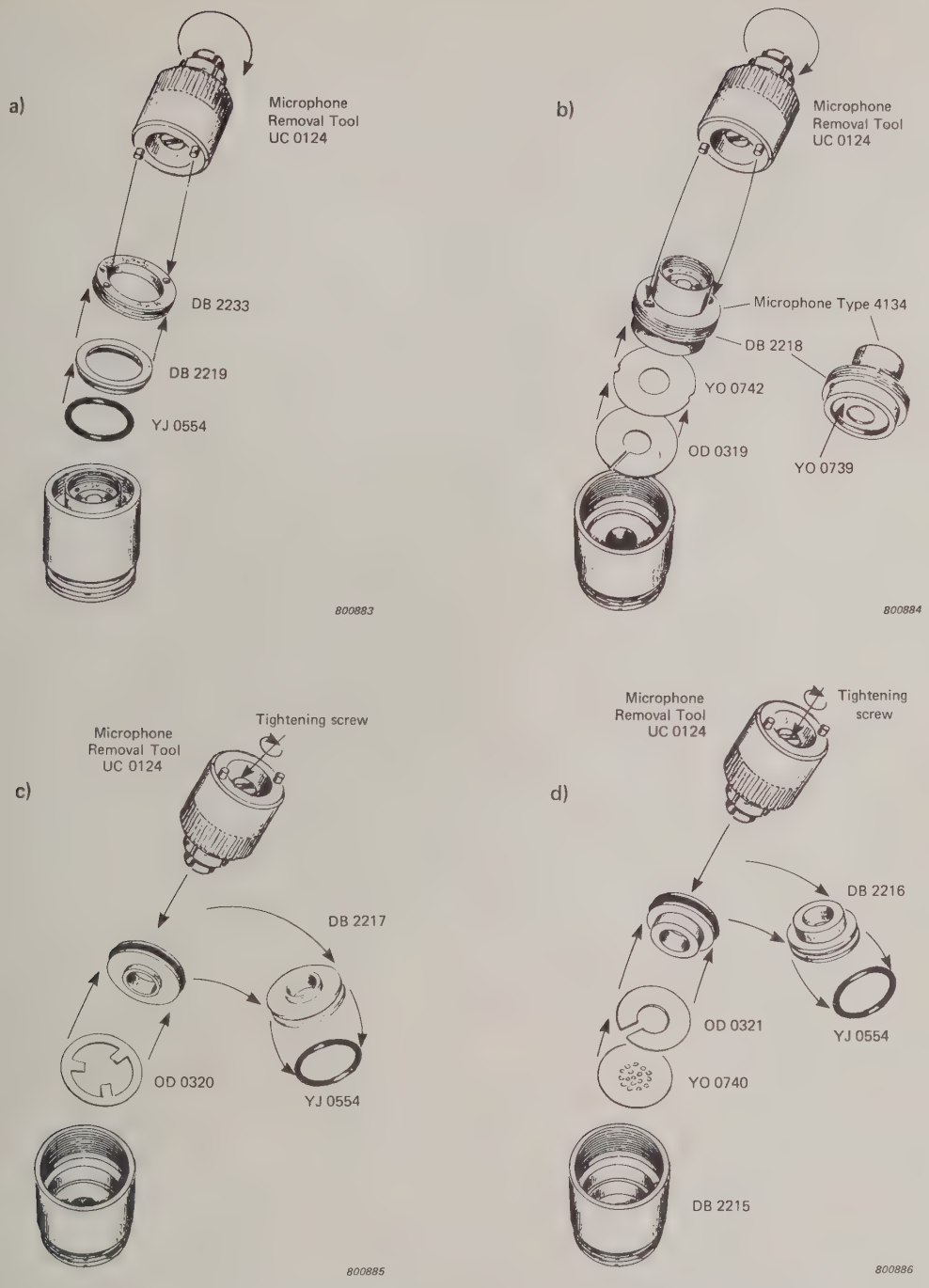
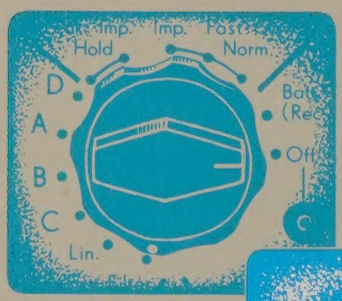
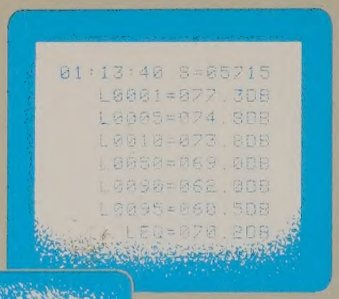
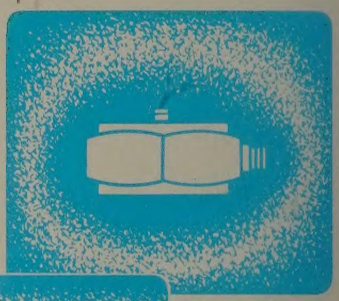
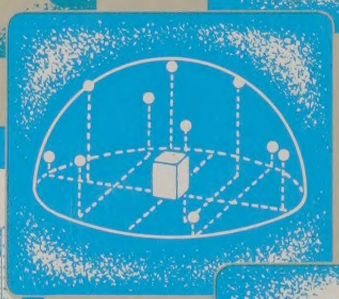


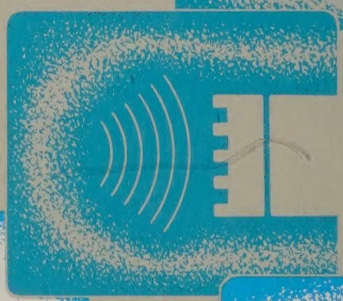
Fig.4.1. Dismantling procedure and part numbers for the Ear Simulator Type 4157

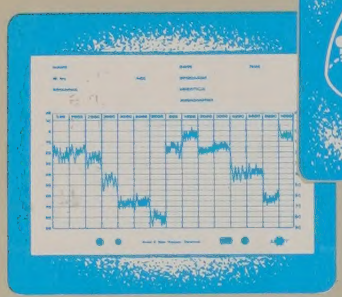


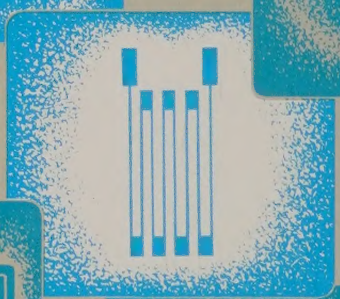


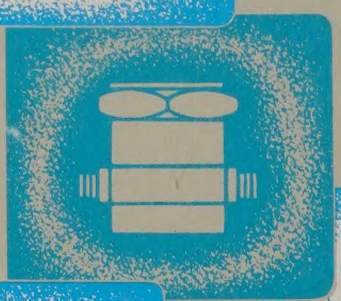


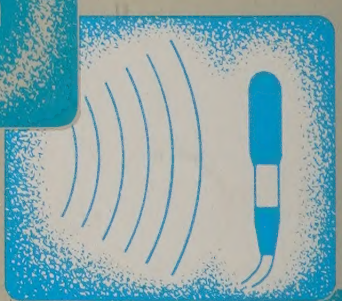


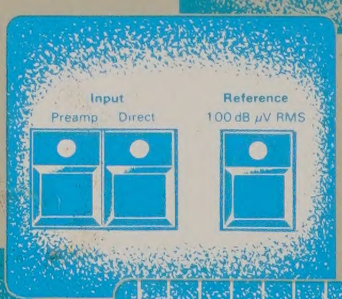


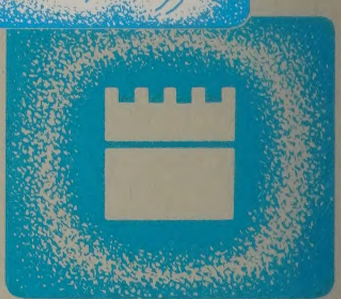


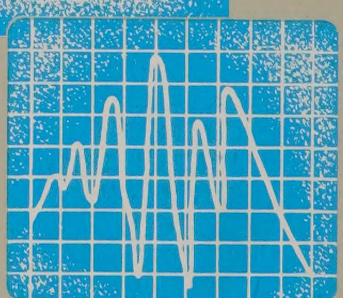












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